

Precision Public Health Opportunity: Heat-Associated Mortality Greater among Pilgrims during Hajj

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Studies on the relationship between ambient temperatures and human mortality have been carried out predominantly in the temperate climates of Europe, North America, and East Asia.¹ Most of these studies have focused on resident populations, but across the globe, transient populations—including migrant workers, refugees, and attendees of mass gatherings—are expanding.²

To fill gaps in data on other geographic locations and transient populations, researchers recently published in *Environmental Health Perspectives*³ an analysis of heat exposure at one of the world's largest mass gatherings in a desert climate: Hajj. This annual religious pilgrimage can bring more than 2 million visitors from a reported 180-plus countries around the world to the holy city of Mecca, Saudi Arabia.⁴ The occasion provides a unique opportunity to compare heat-related mortality risk in these pilgrims with that in the city's year-round residents.

The researchers found better adaptation to heat among residents than among pilgrims. Elevated temperatures had an immediate strong and sustained effect on the mortality risk among pilgrims, but little change in risk among Mecca residents.

Although neither hot nor cold temperatures were significantly associated with mortality risk for year-round residents, the team estimated that 71% of deaths among pilgrims could be attributed to elevated temperatures. This heat-attributable mortality is at least 40 times higher than previously reported in populations elsewhere.^{1,5}

As another way to evaluate the pilgrims' vulnerability to heat, the researchers considered the temperature associated with the fewest deaths. This minimum mortality temperature (MMT) was 23.5°C (74.3°F) for pilgrims and 26.0°C (78.8°F) for Mecca residents. The MMT, an indicator of human adaptability to local climates, varies widely around the world^{6–8} and is higher in warmer than colder locations.^{1,9} Globally, when measured in resident populations, the MMT often coincides with the 75th percentile of the local temperature distribution.¹⁰ In regions with limited access to data on health and mortality, a percentile-based threshold can serve as a tool to characterize heat vulnerability.¹⁰

The researchers analyzed nine Hajj seasons (2006–2014), defined as 2 months of the Islamic lunar calendar.³ This period captures the 2–4 weeks that most pilgrims spend in Mecca,



The annual religious pilgrimage known as Hajj can bring more than 2 million visitors to the holy city of Mecca, Saudi Arabia. Image: © Jasmin Merdan/Getty Images.

including 5 specific days on which they perform the physically demanding Hajj rituals. Because Hajj follows the lunar calendar, its timing shifts (on the Gregorian calendar) by about 11 days each year. Analyzing this series of 2-month intervals across 9 years required a more complex statistical modeling framework than would be needed for a continuous 9-year data set.

The researchers combined data for about 19,000 nonaccidental deaths (8,500 Mecca residents, 10,500 pilgrims) with satellite-based daily ambient temperatures from the U.S. National Oceanic and Atmospheric Administration.³ The study's nine Hajj seasons spanned Mecca's cooler season (September to January) with a median daily temperature of 30°C (range: 19–37°C). On average, deceased pilgrims were 9 years older than deceased residents, which may explain some of the heat-related mortality difference. Hajj pilgrims have previously been reported to have more underlying health conditions (which increase with age) than Mecca residents.³

“Our results highlight the importance of precision public health measures that account for the difference in temperature vulnerability of transient populations compared with local residents, especially in regions with extreme temperatures,” says Saber Yezli, the paper's first author and the director of research at the Global Centre for Mass Gatherings Medicine at the Ministry of Health in Riyadh. “These include not only attendees of mass gatherings, such as large sporting, music, or religious events, but also migrant workers, refugees, and displaced populations.”

Precision public health measures to mitigate the greater impact of extreme temperatures on vulnerable populations may include, for example, different heat warning thresholds for transient and local populations and health care system preparedness, says Yezli. These could supplement measures the Saudi government has already put in place to help prevent heat-related illnesses during Hajj, including distributing educational materials, erecting mist sprayers and air-conditioned tents, and making water and umbrellas freely available.¹¹

For Barrak Alahmad, a research fellow at Harvard University, the study shows that more research is needed on migrant health. “Climate change is causing mass migration in many parts of the world,” says Alahmad, who was not involved in the study. “Public health officials need to be aware that these migrant populations are much more susceptible to extreme temperatures.”¹²

Shakoor Hajat, a professor of global environmental health at the London School of Hygiene and Tropical Medicine, agrees with Alahmad that climate change is increasing the risk to vulnerable individuals,¹³ such as those who are homeless¹⁴ and those who are pregnant.¹⁵ “I was shocked about the high heat-attributable mortality among pilgrims,” says Hajat, who also was not involved in the study. “This is a powerful demonstration that heat is an invisible killer. Many of the heat-related pilgrim deaths are preventable by offering better protection with targeted public health guidance.”

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